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Some Problems for Postwar Musical Acoustics

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INTRODUCTION

SEVERAL years ago Professor G. W. Stewart suggested that the acoustics of music is important enough to warrant a permanent committee in the Acoustical Society of America to foster additional research in this field. It was his thought that such a committee would represent the Society in the encouragement of improvements in musical instruments and in other musical matters where the science of acoustics and the art of music share common interests. At the request of the Executive Council of the Acoustical Society of America, it was the writer's privilege to start an inquiry into the possible functioning of such a committee on music, but this inquiry was interrupted by the advent of the war. Now, in anticipation of the return to peacetime pursuits by members of this Society, it appears appropriate again to invite comments upon this proposed committee.

To aid in estimating the actual need for the projected committee, a request was included in the preliminary inquiry for specific problems meriting study in musical acoustics. The responses to this request were generous; a résumé of the problems submitted is given here in order to provide a basis for understanding what work might be encouraged by the proposed committee. Moreover, the problems[1] are believed to be of some intrinsic interest aside from their relation to the proposal.

The problems are taken up in the order of what may be called basic studies, criteria and standards, and new instruments both for playing and for measurement. The problems are stated as comprehensive questions so as to consolidate specific suggestions submitted by different individuals. Remarks following the questions and the references are in no wise comprehensive, but are only illustrative.

BASIC STUDIES

Since music involves both the physical stimulus and the subjective effect thereof, basic studies certainly must embrace the psychology of music as well as the physical nature of the sound producers. As to the latter, it may be noted that the statement[2] of nearly a decade ago is still true, that it is not possible to design by theory alone a wind instrument to produce a specified tone.

[1] Still other problems, particularly on new tone qualities, have been proposed by V. O. Knudsen, J. Acous. Soc. Am. 11, 29–36 (1939).

[2] D. C. Miller, *Anecdotal History of the Science of Sound* (The Macmillan Company, New York, 1935), p. 43.

Research, both theoretical and experimental, is needed on the fundamental shapes of musical instruments and on the physical properties of materials used in construction as well as of the vibrating media.

Problem 1. How Do Changes of Weather Affect the Tuning or Tone Quality of Stringed Instruments?

The sound board of the usual piano absorbs moisture, swells, and through the bridge changes the lateral force applied to the strings. As a consequence, in climates which experience winters of low humidity (indoors) and summers of high humidity, the tuning of an ordinary piano may rise nearly half a semitone from winter to summer. The effect is roughly uniform throughout the instrument so the piano stays more or less in tune with itself although there is a tendency for irregularities to occur on strings adjacent to the breaks in stringing. The problem to be solved, of course, is to inhibit the absorption of moisture. However, the investigation of the effect as it occurs in pianos now in use is an appropriate preliminary to a check on the efficacy of any remedial treatment.

Problem 2. How Do Changes of Weather Affect the Tuning of Wind Instruments?

The basic knowledge needed for the effect of weather on wind instruments is the velocity of sound in the air *inside* the instrument. The dependence of the velocity of sound on temperature and humidity is known reasonably well[3] but the distribution of temperature and humidity within wind instruments is almost unknown. This distribution is dependent upon the size of the cavity to be filled by the player's breath and, in the case of the woodwinds, upon the holes which are opened from time to time along the tube. The air in the bell of a sousaphone must be nearly at the ambient temperature whereas in the piccolo, practically enveloped by the hands of the player, the temperature of the air probably approaches that of the body. It is thus apparent that in the large instrument the velocity of sound (and thus the frequency produced) is more dependent upon ambient temperature[4] than it is in the small one.

A band which marches and plays in early spring with snow on the ground may, during the following summer, play in a city park where the temperature is 90°F. The wind instruments will thus experience a range of ambient temperature exceeding 50°F with the result that even instruments of moderate size may change their tuning by nearly half of a semitone.[5] Larger instruments may be affected half again as much. In some "brass" instruments compensation for the temperature effect is possible by the adjustment of tuning and valve slides but the use of a tuning slide on woodwind instruments affects the internal tuning detrimentally.

CRITERIA AND STANDARDS

Founded upon the basic studies are criteria and standards which are needed to promote continuity of musical excellence. These may be standards for the adjustment of instruments by performing musicians, or criteria to be used by the acoustician in measuring the improvement of a musical instrument.

Problem 3. For a Wind Band Can a "Variable" Standard Pitch Be Found, Dependent upon Ambient Temperature, so that the Instruments Will Remain in Tune with Each Other Better than Is Possible with a Fixed Standard of Pitch?

At ordinary temperatures, the pitch of all wind instruments rises with increasing ambient temperature, although at differing rates. Since a large fraction of the modern band consists of clarinets it has been suggested that the frequency-temperature dependence of this instrument be taken as standard, so as to constitute a compromise pitch within reach of all wind instruments. This would mean that the standard pitch would rise slightly with increasing ambient temperature. On the other hand, the mallet-played instruments go flat with increasing temperature, so it may be better to try to hold the band as a whole to a

[3] Hardy, Telfair, and Pielemeier, J. Acous. Soc. Am. **13**, 226–233 (1942).

[4] D. J. Blaikley, *Acoustics in Relation to Wind Instruments* (Boosey, London, 1890).

[5] R. R. Pottle, "Intonation problems in school bands," Ph.D. thesis, George Peabody College for Teachers, Nashville, Tennessee (1943).

fixed pitch standard. A careful comparison is needed on all instruments of the temperature dependence and the degree to which compensation is possible by the use of tuning slides. In any event, it should be noted that this suggestion refers only to the use of wind instruments at extreme ambient temperatures, it being the intention that at normal temperature the standard pitch of the *A* of 440 cycles/sec. would still be maintained.

Problem 4. In What Terms May the Musician Adequately Describe the Characteristics He Wants in a Musical Sound?

There is the case of a musician who described a certain clarinet tone as glassy—the reader may judge whether this means smooth as glass or cutting as the edge of a broken glass. A trombone player reported that a certain instrument when played in the theater where he worked was not satisfactory because the tone "spread" too much. This man did not want a directional instrument; the physical characteristics of the "spreading" trombone tone which he disliked are still unknown.

Unless physical descriptions are forthcoming less cumbersome than those we now have, qualitative terms will still be used by the musician to describe the sounds with which he works. For example, what are the physical counterparts of tones generally referred to by musicians as mellow, rich, shrill, full? To establish some equivalence[6] between the qualitative and quantitative descriptions is a necessary step in giving the musician the effects he desires.

Problem 5. In Physical Terms What Is Good Musical Tone Quality?

This apparently simple question in psychoacoustics branches far and wide, both in the perceptual judgment of excellence and in the method of physical description. Within what physical limits is a tone considered "good"? To what extent do peoples of different races agree on a standard of good musical tone quality? Should the standard of cymbal tone, for example, be applied to a flute tone? In physical measure, what makes the cymbal tone good? The physical description must certainly include the manner in which tone is initiated[7] and decays.

Problem 6. What Constitutes a Detectable Improvement in Tone Quality?

If it were possible to increase the output of the eighth, ninth, and tenth partials in the tones of a certain oboe each by 3 db would this be a worthwhile improvement? Indeed, would the ear detect the difference? If such a change does result in a detectable[8] improvement, *how much* is the improvement so that one may judge whether the increased cost to make the change is justified? Are the criteria for oboe applicable to other musical instruments?

NEW DEVICES

New devices are needed for physical measurement of musical sound, for psycho-acoustic studies relating to music, for the active playing of music. Electronic devices have become indispensible in the first two categories and are showing increasing promise[9] in the third.

Problem 7. Is the Usual Equal Temperament the Best Compromise Tuning Possible?

A nineteen-tone temperament has been urged by Yasser[10] as a scale much superior in its musical resources to the equal temperament now in vogue. In this new temperament the octave is divided into nineteen equal parts instead of twelve. For a really fair trial of the nineteen-tone temperament there would be needed:

(1) A variety of **instruments** with new mechanism so that the fingers could handle the seven additional tones in each octave, the development cost of which would have to be borne by someone.

(2) **Music** written for the new instruments and/or a suitable notation to indicate from present music what tones are to be produced.

(3) **Musicians** willing to expend the effort to gain proficiency with the new notation and new instruments, comparable to that they have acquired with the present system.

[6] P. H. Bilhuber and C. A. Johnson, J. Acous. Soc. Am. **11**, 318 (1940).

[7] A. W. Nolle and C. P. Boner, J. Acous. Soc. Am. **13**, 149–155 (1941).

[8] Don Lewis and M. J. Larsen, J. Acous. Soc. Am. **8**, 207 (1937).

[9] B. F. Miessner, Proc. I. R. E. **24**, 1427–1463 (1936).

[10] J. Yasser, *A Theory of Evolving Tonality* (American Library of Musicology, New York, 1932).

Since these three factors depend upon each other to a considerable degree, they constitute a typical circle of obstacles which must be overcome in promoting any radically new musical instrument.

Problem 8. In a Small Piano How Can the Fundamental Frequencies from the Bass Strings Be Strengthened?

Even in large pianos the tones of the bass strings consist principally of the higher partials, and in pianos of the "spinet" type the preponderance is accentuated. The expedient of long strings[11] under great tension is not available in the small piano. Thus a new method of construction is needed whereby the fundamental frequencies in the bass tones of the small piano may be made more prominent.

Problem 9. Can a Device Be Constructed of Both Sufficient Precision and Speed to Record Faithfully a Measure of the Fundamental Frequencies Produced During the Performance of Music?

There has been much philosophizing about the particular temperaments, or tunings, used by skillful musicians. Experimental evidence[12] has been collected with available techniques on how instruments and musicians behave in action, and much more can be accomplished, but a new device or an elaboration of old ones is required to measure frequency in the presence of the complex sounds of actual performance. Observations are needed during ensemble performance because in solo playing there is not the necessity for compromise with other instruments. Moreover, by acoustic coupling[13] one instrument may influence the frequency produced by another. All this requires high speed operation, and still higher speed may be needed to record the transient frequency[14] (if such it may be called) that may accompany the initiation of a tone.

[11] W. B. White, J. Acous. Soc. Am. **12**, 409–411 (1941).
[12] *Objective Analysis of Musical Performance*, C. E. Seashore, Editor, Iowa Studies in Psychology of Music, Vol. IV (1936).
[13] H. Seiberth, Hoch:tech. u. Elek:akus. **45**, 148–158 (1935).
[14] M. Grützmacher and W. Lottermosser, Akustische Zeits. **5**, 1 (1940). See J. Acous. Soc. Am. **12**, 310 (1940).

Problem 10. How Can an Analyzer Be Made Which Will Delineate Changes in Tone Quality Occurring as Rapidly as the Ear Can Appreciate Yet Record the Analysis in a Form Suited to Statistical Treatment?

Parallel to the preceding tuning problem is that of analyzing the quality of tone produced during normal performance. Present methods are too cumbersome to handle statistically the mass of information needed for an adequate physical description even of the steady tone quality of one kind of instrument. Moreover, the transient quality[15] may be even more characteristic of a given instrument than the steady tone.

There has been a tendency to publish a single oscillogram, or possibly an harmonic analysis thereof, implying it to be typical of an instrument. It is common experience that the quality of tone is not the same throughout the range of an instrument, so in addition to a typical tone a statement is needed on how great is the deviation from the typical.

In the normal playing range of the clarinet, for example, some fifty different tones are possible. Before a typical tone is selected information should be available on all fifty. But the same player does not, on the same instrument, repeat exactly. As a minimum should each tone be tested 20 times? But players differ among themselves. For a start, consider five players. Different makes of clarinets are said to have different quality. Perhaps one might take five makes, ignoring the fact that each maker usually offers several models. Thus one must consider fifty tones, twenty tests per player, five players, and five makes—25,000 tests of tone quality before a statement can be made at all comprehensive about the tone quality of a clarinet!

CONCLUSION

Many of these problems are to a certain extent distinct, yet in a broader sense they overlap in that the results of many researches combine to give the musician a better musical scale, or an instrument more versatile, or of better tone

[15] Trendelenburg, Thienhaus, and Franz, Akustische Zeits. **3**, 7–20 (1938).

quality, or more simple to play, or of lower cost (and thus within reach of more people) than any now available. To encourage these researches, as by bringing to the attention of educational institutions problems submitted by musicians and manufacturers, would be a function of the proposed committee for music in the Acoustical Society of America.* Another function of the committee could be to arrange for the continuation of research which has served its initial investigator's problem but which is still incomplete as to its musical implications.

It is the opinion of some that those in the Acoustical Society of America interested in problems relating to music will need no further encouragement. Others feel that a standing committee would assist to a worth-while degree in making the science of acoustics accessible to the musical public generally. To provide a basis for further recommendations and action by the Acoustical Society of America, the writer will welcome comments both as to the possible utility of a music committee and its functions.

* *Note added in proof:* Professor G. W. Stewart has commented that "The Society has in its membership some who are highly trained in music as an art and also in acoustics as a science. These members should have an outlet of expression of opinion which would be more effective than if from one individual. They could give appropriate encouragement and suggestions to manufacturers of musical instruments and they could be influential in the elimination of inaccurate and otherwise unfortunate advertising."

A Clinical Comparison of Air and Bone Conduction Hearing Aids in Cases of Conductive Impairment of Hearing

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(Received July 26, 1944)

THE question of recommending air or bone conduction hearing aids in cases of impairment of the conducting mechanism, where theoretically bone conduction instruments seem to be indicated, is still a moot one. The uncertain status of preference is reflected by the wide range in the number of bone conduction units purveyed through customary commercial outlets. It is significant that some hearing aid manufacturers do not produce bone conduction units, implying that wherever a hearing aid can be of value it should be of the air conduction type. It is the purpose of this paper to present comparisons of performance of air and bone conduction hearing aids, under clinical conditions, in cases of conductive impairment using improvement in speech intelligibility and pure tone gain as evaluative criteria.

Consideration of the literature points up the disagreement concerning the advisability of suggesting bone conduction units. Bunch,[1] Hallpike,[2] and Berry[3] indicated that the value of bone conduction aids has been greatly overemphasized. The Ewings and Littler[4] working with cases of mixed deafness reported results unfavorable to bone conduction. Langenbeck[5] preferred air conduction in all cases with a rare exception made in favor of bone conduction. Fowler[6] also favored air conduction.

Of thirteen cases of conductive impairment Brandt,[7] using the "Siemensphonophor," reported favorable results by bone conduction in six cases with six other cases yielding better performance by air conduction. The remaining case did equally well with either type of instrument. Holmgren[8] favored bone conduction in cases of low frequency loss where hearing for higher tones is not seriously impaired, but where high and low tones are impaired, despite a conductive involvement, he preferred air conduction. Interestingly, Holmgren's inference that a conductive lesion may exist with losses for both high and low tones was supported by Perlman[9] who disagreed with a widely held concept that loss of hearing acuity for low frequencies indicates a conductive lesion and loss for high ones, a nerve lesion.

Of 97 users of hearing aids reporting to Hughson and Thompson[10] nineteen used bone conduction instruments and fourteen users indicated that they were very well pleased with their performance "despite the fact that several of these patients had loss for high tones and two had bone conduction which was definitely inadequate for the hearing aid, with notable loss at 2048 cycles and above."

Kranz[11] and Knudsen and Jones[12] looked with favor on bone conduction in cases of conductive impairment and the former recommended it in cases of mixed deafness. Watson,[13] indicating that the bone conduction area was large enough to include frequencies and intensities of speech sounds, suggested that persons with hearing impairment of the conductive type might utilize bone conduction hearing aids to good advantage. Senturia, Silverman, and Harrison[14] reported that in nineteen cases of conduction deafness no generalization could be made as to the type of instrument to be prescribed.

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[1] C. C. Bunch, Trans. Am. Acad. Ophth. Otol., p. 163 (March–April, 1942).
[2] C. S. Hallpike, J. Laryng. Otol. **49**, 240 (1934).
[3] G. Berry, Laryngoscope **49**, 912 (1939).
[4] A. W. G. Ewing, I. R. Ewing, and T. S. Littler, "The use of hearing aids," London Medical Research Committee, Special Report No. 219 (1936).
[5] B. Langenbeck, Zeits. f. Hals-Nasen-Ohren **40**, 201 (1937).
[6] E. P. Fowler, Jr., Proc. Roy. Soc. Med. **36**, 391 (1943).
[7] A. Brandt, Zeits. f. Laryngol. **26**, 171 (1936).
[8] L. Holmgren, "Hearing tests and hearing aids, a clinical and experimental study," Acta Otolaryng. Supplement 34 (1939).
[9] H. B. Perlman, Arch. Otolaryng. **37**, 680 (1943).
[10] W. Hughson and E. Thompson, Arch. Otolaryng. **38**, 253 (1943).
[11] F. W. Kranz, "Hearing aids," Sonotone Corporation (May, 1940).
[12] V. O. Knudsen and I. H. Jones, J. Am. Med. Assn. **111**, No. 7 (Aug. 13, 1938).
[13] N. A. Watson, J. Acous. Soc. Am. **9**, 294 (1938).
[14] B. H. Senturia, S. R. Silverman, and C. E. Harrison, Ann. Otol. Rhinol. Laryngol. **52**, 131 (1943).

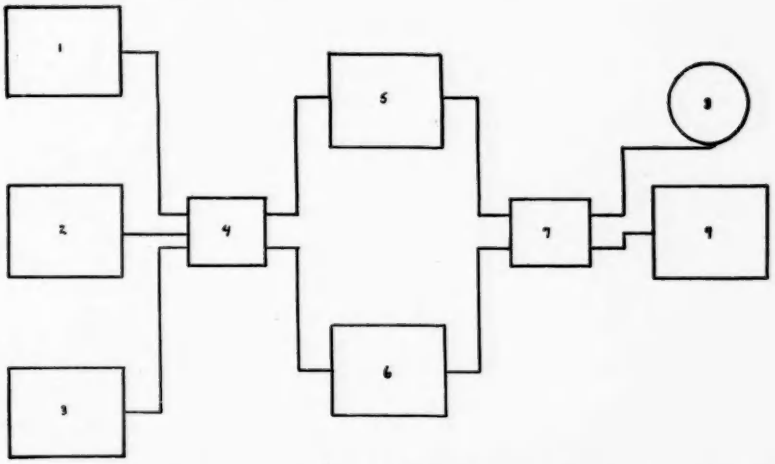

FIG. 1.—Diagram of apparatus—hearing aid clinic. Unit 1—WE 2A audiometer. Unit 2—ET reproducer. Unit 3—Microphone. Unit 4—Input selector switch, matching equalizers. Unit 5—12-watt amplifier, calibrated attenuation. Unit 6—30-watt amplifier, calibrated attenuation. Unit 7—Output selector switch. Unit 8—Output volume indicator. Unit 9—Dual-speaker system.

APPARATUS

The apparatus used in evaluating the performance of the hearing aids was that described by Senturia, Silverman, and Harrison.[14] An elaboration of the apparatus in Fig. 1 follows.

1. The Western Electric 2A audiometer was selected as a pure tone source because it is battery operated, it has stable frequency calibration, it has no hum, and there is less than one percent harmonic distortion. Although it uses a compensated oscillator, the compensation was measured electrically and suitable equalizers were inserted in the circuit, so that the over-all characteristics were essentially uniform. Because of the mechanical characteristics of the earpiece supplied with the instrument, a special coupling transformer was devised which provided suitable compensation.

2. A special 30-watt amplifier unit was designed and constructed to provide sufficient amplification plus reserve power with less than two percent distortion, as measured with a General Radio noise and distortion meter. Its frequency characteristics were linear, plus or minus one decibel from 60 to 10,000 cycles per second.

3. An electrical transcription turntable which revolves at either 78.24 or $33\frac{1}{3}$ revolutions per minute and a reproducer with a dual-speed motor were used. The reproducer was of the crystal type, imposing a needle pressure of 35 grams, and was mounted on a broadcast type reproducer arm which handles records up to 17 inches in diameter. The reproducer was connected to the amplifier through a special equalizer, which possessed mirror characteristics to those used in recording the special test electrical transcriptions. Inasmuch as the transcriptions used were recorded in the Central Institute laboratories under ideal conditions, recording and reproducing characteristics could be accurately measured.

4. A dual-speaker system was arranged by mounting two concert-type Jensen electrodynamic speakers in an appropriately designed cabinet which had adequate baffling to provide uniform response to 50 cycles per second. This baffle cabinet was a felt-lined acoustic labyrinth which utilized back pressure to reinforce frontal radiation in the proper phase. The direct current field supply was obtained from a unit which formed an integral part of the speaker system.

5. The volume level indicator consisted of a Western 01 MA meter with an 8-inch dial. The rectifier was of the copper oxide type and the attenuator was a constant impedance *H* pad arrangement, eliminating any reflection which might introduce phase distortion.

6. Calibrated attenuation with two intensity controls was provided, one control for the pure tone test and the other for the sentence test

TABLE I. Comparison of air and bone conduction hearing aids in cases of conduction impairment based on differences in perception of speech.

Type of instrument	Number of cases	% of total cases	Mean difference in speech perception scores*	Standard deviation	Mean deviation	Median difference in speech perception scores
Better by air conduction	32	43.8%	26.6%*	18.7	14.4	25
Better by bone conduction	24	32.9%	15.8%*	7.75	6.76	16.0
Equal performance	17	23.3%				
Total	73	100%				

* Average amount by which one type of instrument exceeded other type.

TABLE II. Comparison of air and bone conduction hearing aids in cases of conductive impairment based on differences in pure tone gain.

	Frequency								
	512 c.p.s.			1024 c.p.s.			2048 c.p.s.		
Type of instrument	Number of cases	% of total cases	Mean difference in pure tone gain	Number of cases	% of total cases	Mean difference in pure tone gain	Number of cases	% of total cases	Mean difference in pure tone gain
Better by air conduction	39*	53.4%	12.2*	46	63.0%	13.7*	49	67.0%	16.1*
Better by bone conduction	21	28.7%	10.3**	17	23.3%	7.7**	11	15.1%	9.6**
Equal performance	13	17.9%		10	13.7%		13	17.9%	
Total	73	100%		73	100%		73	100%	

* Average gain in decibels over bone conduction.
** Average gain in decibels over air conduction.

electrical transcription. Dial markings were indicated so that all tests made with this apparatus were uniform. All alternating current wiring was installed in conduit with a single master switch, further simplifying operation.

7. Phonograph records were discarded in favor of electrical transcriptions since the frequency range of the latter is much wider, varying from 100 to 9000 cycles per second as compared with 150 to 4000 cycles per second for the average phonograph record. An electrical transcription of the type used for these tests has a background noise of less than 55 decibels below recorded level, which is 25 decibels less than the newest type phonograph record. The transcription had four separate tests on one side, each test consisting of 25 selected sentences, carefully enunciated at a constant voice level by a professional announcer. This feature eliminated the need for changing records during the test.

8. The chair in which the individual was seated during the tests was located so that the ears and hearing aid were two meters from, and at right angles to, the calculated points of the source of sound.

9. The laboratory which housed the special equipment was selected because of its acoustical properties and average residual noise level. Reverberation time (time required for a 1000-cycle tone to attenuate 60 decibels or to 1/1,000,000 of its original value) was one second, and the noise level averaged 35 decibels above absolute threshold (pressure 200 microdynes cm^2 at 1000 cycles per second, intensity 10^{-16} watt cm^2 at 1000 cycles per second).

PROCEDURE

Of approximately 500 cases exposed to the hearing aid service of Central Institute for the Deaf, 73 were selected which met the criteria for conduction deafness as suggested by Holmgren[8] and modified by Senturia and Thea.[15] These basic criteria were normal or slightly decreased bone conduction, negative Rinne, and a normal or retracted tympanic membrane. Many of these cases appeared to be classical examples of otosclerosis or hyperplastic otitis media. The

[15] B. H. Senturia and A. Thea, Laryngoscope **52**, 673 (1942).

first step in testing was the pure tone air and bone conduction audiometer test using the Maico D5 instrument. The threshold measurements were derived in a clinical testing room with a residual acoustic level of approximately 35–40 decibels as measured by a Western Electric RA330 sound level meter.

The patient was then tested binaurally with the apparatus previously described in the room housing the equipment. The pure tone and sentence tests (25 selected sentences from the Fletcher-Steinberg[16] lists) were administered to the unaided ears. The tests were then repeated using the hearing aids to be evaluated and the improvement (or lack of it) in pure tones and speech understanding was noted. An average of six widely used hearing aids including air and bone conduction units were tried in each case. Attention in this report is focused on the comparison of performance between the air and bone conduction units. In each case the units of each type yielding the optimum score on speech intelligibility were compared and the differences

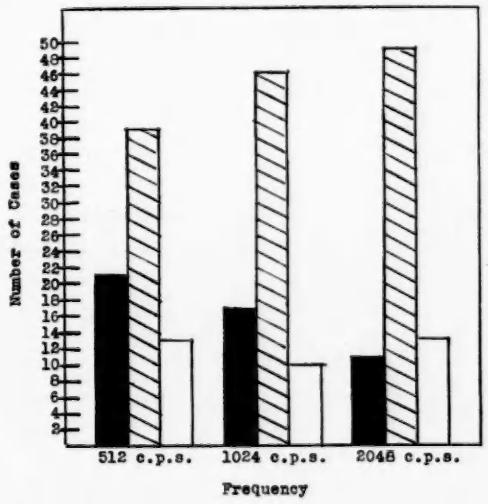

FIG. 2. Comparison of number of cases of conductive impairment showing superior or equal performance by bone and air conduction based on pure tone gain. Solid black, better by bone conduction. Black and white, better by air conduction. Solid white, equal in performance.

indicated. The scores of these instruments were then contrasted in terms of the improvement at 512, 1024, and 2048 cycles per second.

[16] H. Fletcher and J. C. Steinberg, Bell Sys. Tech. J. 8, 806 (1929).

RESULTS

1. Table I indicates that on the basis of the speech intelligibility test better performance was shown in 43.8 percent of the cases by air conduction and in 32.9 percent of the cases by bone conduction, with 23.3 percent of the cases yielding identical performance.

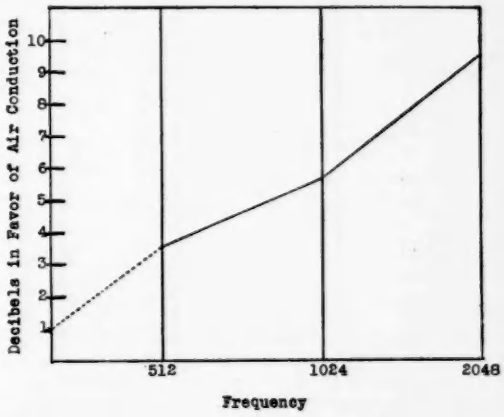

FIG. 3. Average superiority of air over bone conduction hearing aids in cases of conductive impairment based on pure tone gains.

2. Comparing the average amount of superiority of each type, it is revealed that air conduction was more favorable by 10.8 percent. In other words, where air conduction was better it appeared to be superior by a greater amount.

3. A significant number of cases (23.3 percent) showed identical results on the speech intelligibility test.

4. On the basis of pure tone gain at 512, 1024, and 2048 cycles per second, Table II reveals a wide margin of superiority for air conduction and the margin widened with an increase in frequency. At the important frequency of 1024 cycles per second 63.0 percent of the cases were superior by air conduction and 23.3 percent by bone conduction.

5. Where air conduction showed better performance than bone conduction, it was better by a greater amount. Comparing the average amount of superiority of each type at 1024 cycles per second, it is revealed that air conduction was more favorable by 6 decibels.

6. More cases showing identical results occurred at 512 and 2048 cycles per second than at 1024 cycles per second.

7. Figure 2 illustrates graphically how more cases showed better performance by air conduction as the test frequency was increased.

8. When the average difference between pure tone gains by air and bone conduction for all 73 cases was computed, the data revealed a favorable margin for air conduction ranging from 3.6 decibels at 512 cycles per second to 9.5 decibels at 2048 cycles per second as indicated in Fig. 3.

DISCUSSION

The findings seemed to indicate a superiority of air conduction hearing aids over bone conduction instruments in cases of conductive impairment based on both speech intelligibility tests and pure tone tests with the margin of favor under the latter conditions increasing with frequency. The better performance by air conduction in transmission of pure tones was greater in terms of number of cases than the superiority as measured by speech intelligibility tests. This situation is probably brought about by the fact that on speech intelligibility tests the patient is afforded an opportunity to synthesize language stimuli from auditory clues, thus raising his score.

The superior performance of air conduction units with increase in frequency is undoubtedly due to the mass-inertia characteristics of the bone conduction oscillator which affect the transduction of high tones. Furthermore, the transmission characteristics of the conducting media, a critical factor in bone conduction as pointed out by Barany,[17] exercise the same influence.

Despite the pattern of performance revealed by the clinical data, no generalization is warranted with regard to recommending air or bone conduction units in cases of conductive impairment of hearing. Conductive deafness pathologies vary in the affect which they have on responses by the patient to different portions of the frequency spectrum. Perlman,[9] for example, indicated that such pathologies as the existence of pus against the drum and bullous myringitis affecting the impedance of the drum result in a loss for higher tones. Moreover, conditions altering the tension of the tympanum resulting in inequality of air pressure on both sides of the drum, as Campbell and Hargreaves[18] pointed out, takes place in rapid descent in a plane, affects transmission of the low frequencies. Lüscher,[19] contrary to some prevailing notions, suggested that acuity for high tones is affected by middle ear involvements.

Because of the variables attendant upon the qualitative nature of hearing impairment where it occurs as a result of conductive lesion, the fundamental conclusion to be drawn is that evaluation of a hearing aid embodying adequate equipment and measuring techniques must be carried out in terms of responses of the individual patient.

The author is indebted to Mr. C. E. Harrison for design, construction, and description of the apparatus; to Dr. B. H. Senturia and Dr. H. N. Glick for the otologic examinations, and to Miss Audrey Hicks and Miss Mildred Shapiro for technical assistance.

[17] E. Barany, "A contribution to the physiology of bone conduction," Acta Otolaryngol. **1**, Supplement 25–27.

[18] P. A. Campbell and J. Hargreaves, Arch. Otolaryng. **32**, 417 (1940).

[19] E. Lüscher, Acta Otolaryngol. **27**, 250 (1940).

Young's Modulus of Elasticity of Fibers and Films by Sound Velocity Measurements*

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(Received August 8, 1944)

A method for measuring the modulus of elasticity of fibers and films by sonic means is described and the results of an exploratory study of the modulus in various natural and synthetic fibers and films are given. The method is based on the equation for the propagation of longitudinal waves in elastic materials, which expresses the velocity of propagation in terms of the elastic modulus and density of the medium. The procedure involves measuring the sound velocity and calculating the modulus, using the proper density value. The modulus so calculated is characteristic of a dynamic, short period measurement, since a sound frequency of approximately 10 kilocycles per second was used. The range of moduli found was from 1×10^{10} to 50×10^{10} dynes per square centimeter. Correlations of moduli with other physical properties are given.

INTRODUCTION

IN dealing with systems that exhibit both plasticity and elasticity such as fibers and films the usual methods of measuring Young's modulus are apt to give results highly influenced by the presence of the plastic component since in general a low rate of loading is employed. When a load is applied slowly to such a medium, plastic deformation is observed, i.e., one in which complete recovery is not present after the release of the stress. In a good many cases the resultant stretching produces a change of structure, e.g., by increasing the orientation; and it is for these reasons that the usual mechanical methods are not adapted to a study of the truly elastic characteristics of fibers and films. Also it is difficult to apply some of the methods, such as those based on compression, impact, and photoelastic effects. To study the elastic component alone requires a high rate of loading so that the deformation is executed very rapidly, thereby minimizing the relaxation and plastic processes. The problem of obtaining this high rate of loading for such measurements was solved by the use of longitudinal vibrations of relatively high frequency, around 10 kc/sec., an application of sound used previously by Meyer and Lotmar,[1] but in a considerably cruder and less versatile form than that described in this paper. This method was developed with a view to applying it to the study of the fundamental properties of fibers and films and it was hoped that correlations between the dynamic modulus so measured and other properties would give useful information as well as provide another fundamental means of characterizing a structure. This should also be of considerable interest in the study of elastomers, that is, natural and synthetic rubber, plasticized resins, etc. Most measurements reported have been made under relatively low rates of loading whereas a lot of applications, for example, in tires, require high rates. It appears that more work than has been done up to the present would be very worth while particularly at lower frequencies, which conceivably might give much valuable information on relaxation times and other structural parameters. Because of this it is planned to stress the method rather than the results obtained to date and their interpretation.

METHOD

The method used is based on the expression for the velocity of sound in media which are free to shrink laterally when extended longitudinally and expand laterally when compressed longitudinally—that is:

$$V=(E/d)^{\frac{1}{2}},$$

where E = Young's modulus of elasticity, and d = density of the medium. From this it can be seen that E, the adiabatic modulus, can be calcu-

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[1] K. H. Meyer and W. Lotmar, Helv. Chim. Acta 19, 68–86 (1936).

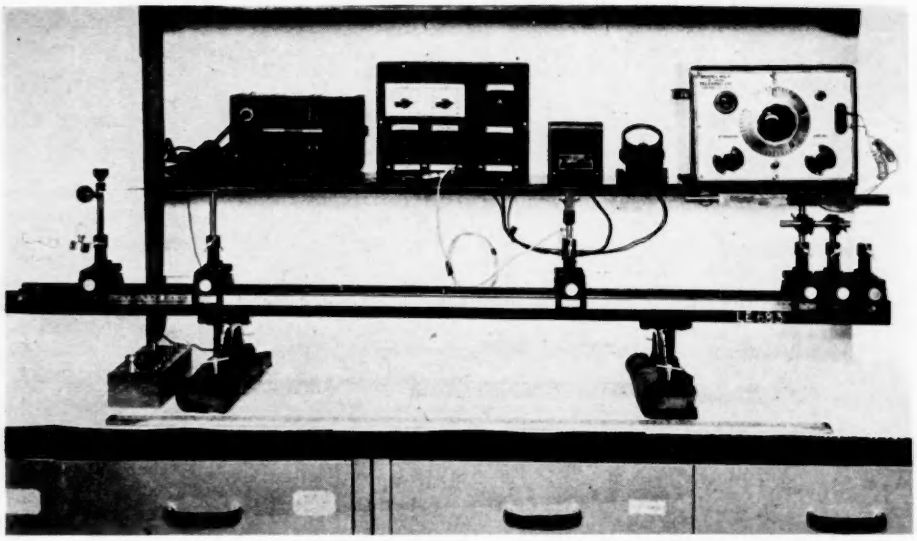

FIG. 1a. Photograph of apparatus for sonic determination of Young's modulus of elasticity.

lated if V and d are measured. This is what was done in the present case with continuous fiber samples and very narrow film strips. It was assumed that this formula applied to these materials without any corrections, which is probably defensible particularly in the case of the fibers which were usually made up of filaments of a very small cross section. It is a fortunate thing that V is independent of the fiber cross-sectional area, thereby making it unnecessary to measure this quantity accurately. This is a distinct advantage not found in the usual methods for measuring Young's modulus. However, it was necessary to know the density of the fibers and films tested, but the literature provided reliable values in most cases.

As mentioned, an experiment of a similar nature was performed by Meyer and Lotmar in which the vibrations were excited by friction both in the test fiber and in a standard fiber with known properties. By varying the length of the standard fiber, the sound frequency produced was made equal to that of the test fiber. From the ratio of the fiber lengths when this condition obtained, the velocity of sound in the test fiber was calculated. This method, while direct, is somewhat inexact, and furthermore requires a standard sample. To do away with this and to increase the precision, the method was modified so that standing waves of a definite frequency were set up in the sample and the half-wave-lengths measured. Knowing the frequency, the velocity was then calculated.

The method of measurement can best be understood by reference to Figs. 1a and 1b. The source of the longitudinal vibrations is a half-wave-length bar of steel to the center of which are attached two Rochelle salt crystals. The bar is clamped in the center and the crystals excited by the audio oscillator. The particular bar and crystal combination used resonated at 9.4 kc/sec. and gave longitudinal oscillations of sufficient amplitude with only a few volts applied directly from the oscillator. At one end of the bar is a clamp for attaching the fiber sample or film strip. The source, along with a pulley and clamp at the other end, is mounted on an optical bench and the sample is run over the pulley and loaded by a weight to give the desired tension or clamped at the desired elongation. Another thin Rochelle salt crystal attached to a support which can move along the optical bench acts both as a reflecting fret and detector of the amplitude of the standing waves when they are set up. The output of this crystal is amplified and read on a meter. As the crystal is moved down the sample away from the source, successive peaks in intensity are noted. What apparently takes place is that the crystal offers a sufficient discontinuity so that some of the energy is returned to the source. When this returned energy is in phase, standing waves are formed and the intensity

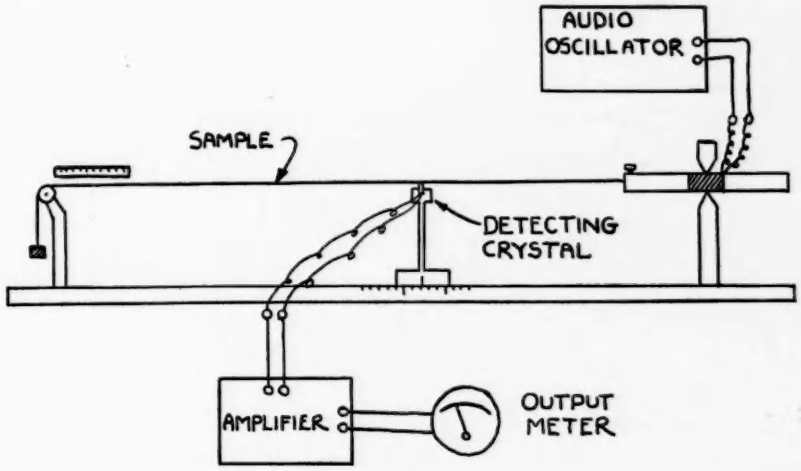

FIG. 1b. Schematic of apparatus.

increase, as shown by the meter, occurs. To determine the half-wave-length, the position of the movable crystal support on the optical bench is noted for two successive maxima, the difference then being the required value. This scheme is preferable because any end effects cancel out.

In operating the above set-up, the sample is put in under a definite load or elongation. The detecting crystal is adjusted for height so that good contact with the sample is insured. This adjustment is very important and some practice is required in finding the optimum condition. The position of the detecting crystal, the amplifier gain, and oscillator output are next adjusted so that a signal of a volt or so appears on the meter. The oscillator frequency is then adjusted for resonance, as indicated by a peak in the meter reading. Next, the crystal is moved along the optical bench until a peak is found, the oscillator output being adjusted during the process to keep the meter on scale. After the region of the peak is found, meter readings every 1 mm are taken and the peak accurately found. The crystal is then moved on to the next peak and a similar accurate measurement made. The small scale was used for measuring sample elongation under various loads, using a fiducial mark on the sample.

In working with fibers, any twist above three turns per inch was removed before any measurements were made. It was found necessary to load all samples initially by a small amount to get good peak readings. This was done in most cases and if the sample was stretched, the elongation was calculated using the length at this loading as the original length. In general, cords twisted from strands could not be tested as the surface was too irregular.

In working with films such as Cellophane, a strip a few mm wide was cut in the desired direction and put in under a load of 100 g. As before, if the sample was stretched, the length at this load was taken as the original length.

To facilitate routine use of this method, graphs were prepared for each common density used, the modulus being plotted *vs.* the half-wave-length at the operating frequency. The half-wave-lengths encountered in the tests ranged from 5 to 30 cm. It was found practical to train an operator to use the set-up for routine testing and it is hoped in the future to be able to adapt the arrangement to a direct reading scheme perhaps by use of a suitable phase meter.

Concerning the accuracy of the results, the following must be said. The peak positions were usually determined easily to ± 1 mm and also it was thought that the frequency was good to $\frac{1}{2}$ percent. This suggests that on the average the absolute results are good to about 3 percent, providing the density figures are correct. Measurements of densities of films by immersion in heavy liquid mixtures indicate that the densities of most regenerated cellulose films are essentially the same. The combined effects of added weight and swelling due to adsorbed water at higher humidities tend to change the density very

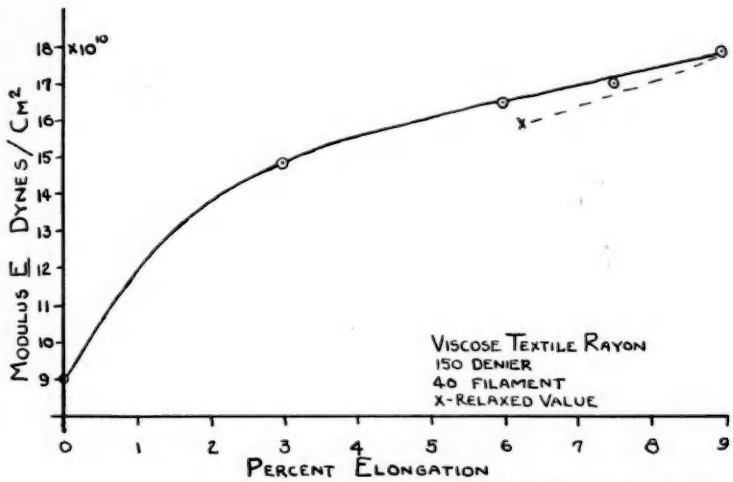

FIG. 2. Variation of elastic modulus with elongation for typical textile yarn.

little as they are both in such a direction as to cancel out. The change in density due to stretching is not known inasmuch as a reliable value of Poisson's ratio for the various materials is lacking. Assuming a reasonable value, however, the change in density due to a 10 percent stretch is of the order of the experimental error in determining the half-wave-lengths.

As a check on the uniformity and reproducibility of the modulus measurements, seventy-five successive one-yard samples of representative viscose rayon textile yarns were tested. In each case the standard deviation was 0.25×10^{10} dynes/square centimeter. As this is approximately the possible error to be expected because of the ±1-mm uncertainty in determining the peaks, it is concluded that a fair degree of uniformity exists and tests on one sample are representative of the portion from which it was taken.

RESULTS

General

The range of moduli encountered in the tests made was from 1 or 2×10^{10} to $45\text{–}50\times10^{10}$ dynes/square centimeter. Of the fibers measured,

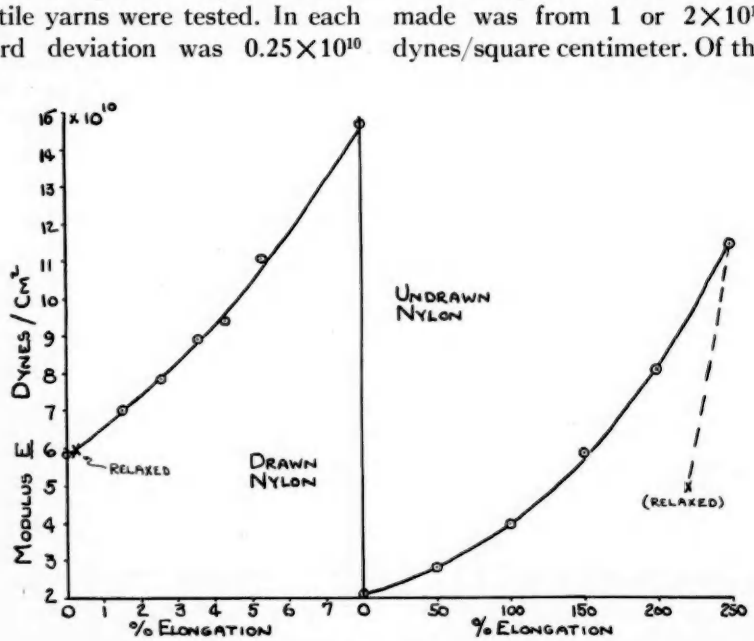

FIG. 3. Variation of elastic modulus with elongation for two types of Nylon.

it was observed that the highest modulus was obtained in a natural fiber, linen, which had been wetted and dried under tension while the lowest was characteristic of wool and undrawn Nylon. Ordinary viscose rayon textile yarns ran from 10 to 30×10^{10} dynes/square centimeter, cellulose acetate yarns somewhat lower, and Nylons lower still. Regenerated cellulose films, such as Cellophane, exhibited very little variation, being all between 8 and 12×10^{10} dynes/square centimeter in the principal or machine direction, with values roughly one-half these in the transverse direction. Cellulose acetate films averaged lower, around 5×10^{10}, and ethyl cellulose films around 3×10^{10} dynes/square centimeter.

That these dynamic moduli are higher than those obtained by essentially static means is shown by comparative experiments on Nylon monofils which indicated that the sound velocity value in this case was about 1.7 times a value obtained by a deflection method under the same conditions. The difference is ascribed to the difference in rate of loading.

Specific (Fibers)

Figure 2 shows some typical results with ordinary commercial viscose rayon textile yarn at 60 percent R.H. and 70°F. The effect of stretching on the modulus value obtained is shown. After each stretch enough time was allowed for practical equilibrium, usually 30 seconds. That some structural change was permanent is shown by the relaxed value, which was obtained by applying the original load after unclamping and relaxing the yarn for some time and measuring the modulus value again.

Figure 3 gives typical results for Nylon showing the markedly different behavior of drawn and undrawn Nylon. Of particular interest is the fact that the drawn material has remarkable recovery properties, the relaxed point coinciding with the initial point, whereas the undrawn material behaves more like the viscose rayon textile yarn, exhibiting a permanent change in structure due to the stretch. Note, however, the different amounts of elongation necessary to produce the same change in modulus.

As would be expected, it was found that the general effect of decreasing the humidity and increasing the temperature is to increase the modulus in viscose rayon fibers. There was no appreciable influence of any of several finishes applied to such yarns, whereas boiling in a soap solution tended to lower the modulus.

A series of fiber samples having progressively higher moduli obtained by stretching samples of the same material was checked for orientation and crystallinity by x-ray diffraction and other methods. The modulus was observed to increase with orientation whereas the crystallinity did not change appreciably.

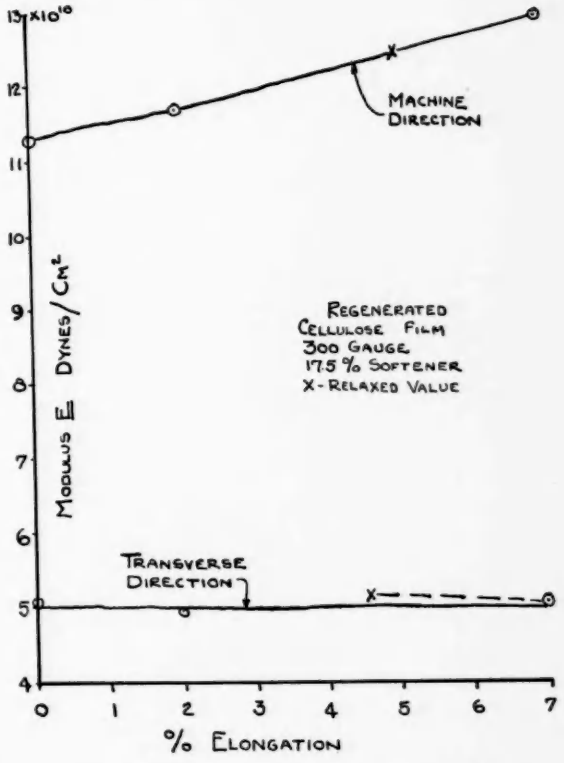

FIG. 4. Elastic modulus as a function of elongation for a typical regenerated cellulose film.

Specific (Films)

Before showing any results in films it must be mentioned that in the manufacture of regenerated cellulose films like Cellophane, the material is subjected to different stresses in different directions. The principal or machine direction necessarily experiences somewhat different conditions in manufacture than does the transverse

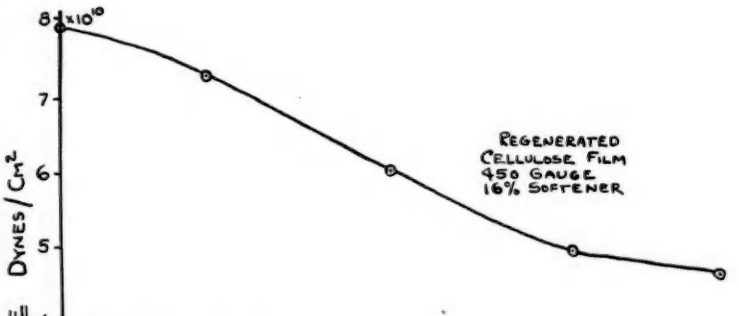

FIG. 5. Variation of elastic modulus with direction in a regenerated cellulose film.

direction and consequently different physical properties in the two directions are observed.

Figure 4 shows results with a typical transparent regenerated cellulose film. The top curve shows how the machine direction modulus varies with stretch and the bottom curve gives the same results for the transverse direction. The anisotropy due to the manufacturing process is evident.

As in the case of fibers, an increase in modulus with decrease in relative humidity and increase in temperature was observed.

Several non-cellulosic films were measured, all of them exhibiting a lower value of the modulus than regenerated cellulose films. In some cases it was found impossible to measure the modulus, no output from the detecting crystal being evident. This was probably due to extreme absorption in these particular materials.

As a check on the variation of the modulus with the direction in the film sheet from which the sample strip is cut, a survey at intermediate angles between the machine direction and transverse direction was made. The results for a

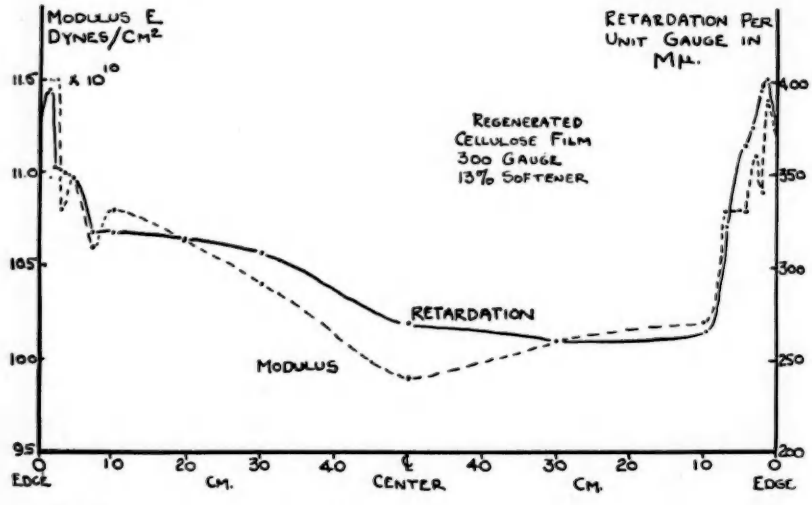

FIG. 6. Correlation of elastic modulus with optical retardation in a regenerated cellulose film

regenerated cellulose and cellulose acetate sample are shown in Fig. 5. As can be seen, the regenerated cellulose sample shows considerable anisotropy while the cellulose acetate structure is essentially isotropic.

Perhaps one of the most interesting experiments made in the present series is the one in which a correlation between the optical retardation or birefringence exhibited by regenerated cellulose film and the elastic modulus was established. The retardation had been known to vary considerably, under some conditions of manufacture, from edge to edge of the sheet, that is, transversely. Strips of film were cut at various points from edge to edge and the modulus and optical retardation measured. The average results are shown in Fig. 6 and it is noticed that the correlation is quite marked showing the parallelism between optical and mechanical effects.

As mentioned earlier, the brief survey of results given is for the purpose of showing applications of the method. No attempt has been made to interpret them in the light of structure, although the implications are obvious in some cases. It is hoped that further work will be fruitful in establishing some useful and interesting relations.

The authors wish to acknowledge the cooperation of the management of the Rayon Department, E. I. du Pont de Nemours and Company in permitting this material to be assembled for publication.

The Velocity of Sound in Vapors

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(Received August 15, 1944)

The study of sound propagation in gases has revealed useful data concerning molecular behavior. Vapors, with little known about their absorption and dispersion to sound at audible frequencies, provide a natural field for extending such studies. In the present investigation, a form of Kundt's tube is employed in which a hot wire records the amplitude in the stationary wave system. It is calibrated by the use of dry air and of oxygen. The results obtained for the velocity of sound are in good agreement with those determined by other methods.

INTRODUCTION

NUMEROUS observations on the propagation of sound of sonic and supersonic frequencies have revealed that only perfect gases of meticulous purity give results in agreement with the classical theories of velocity and absorption. Abnormal behavior of some gases in certain frequency ranges has been noted and theories put forward to account for it. In vapors, however, the reports on velocity and particularly on absorption are scanty.[1–4]

The object of the present investigation is to provide information on sound propagation in a number of vapors having comparatively large vapor pressures at ordinary temperatures. One of the authors[5] has recently reported an anomalous behavior of supersonics in air mixed with water vapor. Railston[6] has also reported an abnormal behavior of some vapors in the supersonic range. The present work can be considered as a link-up with the above-mentioned work in the sonic range of frequencies.

[1] E. H. Stevens, Ann. d. Physik **7**, 285 (1902).
[2] Dixon and Greenwood, Proc. Roy. Soc. **A105**, 199 (1924).
[3] Dixon, Campbell, and Parker, Proc. Roy. Soc. **A100**, 1 (1921).
[4] S. K. Jatkar, Ind. J. Phys. **13**, 445 (1939), etc.
[5] M. Mokhtar, Thesis, University of Durham (1939); M. Mokhtar and K. Matta, Proc. Math. Phys. Soc. Egypt **2** (1944).
[6] W. Railston, J. Acous. Soc. Am. **11**, 107 (1939).

METHOD AND APPARATUS

The diagram of the apparatus is shown in Fig. 1. In principle, it is a Kundt's tube actuated by an electrically maintained source *S* at one end and a movable reflector *R* at the other. The tube is made of copper and is 150 cm long, 5 cm wide, thick-walled, and uniformly wound with a Nichrome heating wire embedded between two layers of asbestos. The sound source is a telephone earpiece of low resistance with its ebonite cover removed and is actuated by an audiofrequency beat oscillator (General Radio Type 713A), calibrated with a set of standard tuning forks. The reflector is a copper disk having a copper-constantan thermocouple soldered to its face and is thermally insulated from its carrier by a short ebonite tube *E*.

For detecting when the tube is in resonance and for measuring wave-lengths as the reflector is moved, the principle of the hot wire anemometer, as adapted by Richardson[7] for acoustic measure-

[7] E. G. Richardson, Proc. Roy. Soc. **A146**, 56 (1934).

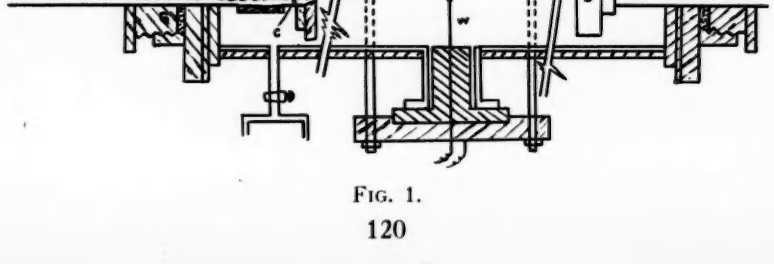

FIG. 1.

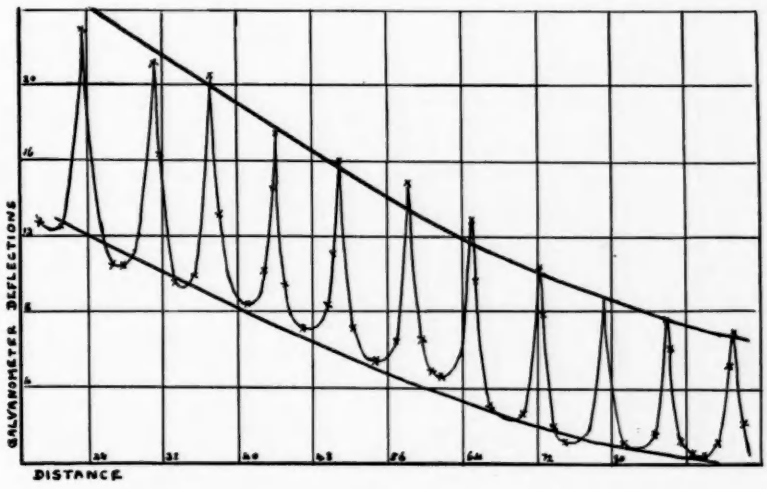

FIG. 2.

ments, was used. A thin platinum wire, 1 cm long and 0.0025-cm diameter, is electrically heated just below red-hot. It is supported by two thin steel wires which exert a slight tension to keep the wire taut. The anemometer is introduced into the tube through a side piece closed with a gas-tight fitting. In the usual method of using a hot wire for measurements of sound absorption and velocity, the reflector is fixed at a resonance position and the hot wire moved between it and the source along the sound track. The change in resistance that it experiences is a measure of the amplitude in the pseudo-stationary wave system set-up. The difficulty in using such an arrangement in the present instance is caused by the necessity of moving the wire through large distances. This is overcome by keeping the wire at a fixed position and moving the reflector. The distance that the hot wire requires to be moved in between two peaks in the resistance values (measured by the deflections of a sensitive galvanometer in a Wheatstone network) is equal to a half-wave-length of the sound in the gas or vapor in the tube. The transmission constant is so large in comparison with the absorption constant of a vapor that the influence of the latter on the former may be neglected.

When carrying out the experiment, values of the galvanometer deflections are recorded against positions of reflector and the mean value of the half-wave-length calculated. Figure 2 shows a specimen plot.

The free-space velocity V is derived from the tube value V_1 by applying the equation:

$$V_1 = V(1-Kc),$$

where c depends on the nature and temperature of the gas and can be calculated from the equation of Dixon and Greenwood. K is a constant embodying the effects of frequency, diameter, material, and shape of the tube and can be evaluated once and for all for the tube by carrying out an experiment on a gas the free-space velocity of which is accurately known. For this purpose air dried by passage over phosphorus pentoxide and made free of carbon dioxide by passage through caustic soda and calcium chloride was used.

RESULTS

The vapors used were those of ethyl ether, acetone, ethyl alcohol, benzene, and chloroform. Each liquid was purified from the main impurities to which it may be liable. Before admitting the vapor into the tube, the heating current in the

TABLE I.

Substance	Temperature	Free-space velocity
Air (standard)	0°C	331.1 m/sec.
Ethyl ether	35°	166.3
Acetone	62°	211.2
Ethyl alcohol	80°	266.1
Benzene	90°	200.0
Chloroform	70°	153.0

coil around it was adjusted to give a temperature as close as possible to the boiling point of the liquid. The tube was pumped out and the liquid admitted in a quantity sufficient to produce saturation. The temperature was readjusted until the manometer registered atmospheric value.

The heating current to the hot wire anemometer needs to be adjusted to suit each vapor and the temperature inside the tube. To facilitate this adjustment, the tube was fitted with a glass window for visual observation of the color of the heated wire. As already explained, the constant K was determined from the dry air results, while c was calculated from the physical constants of the gas. The final results of the free-space velocities for the vapors at their boiling points are given in Table I. A comparison of these results with those of Railston in the supersonic range shows good agreement, except for acetone for which our result is two percent higher.

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The Rayleigh Disk as a Laboratory Instrument

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AND

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(Received August 1, 1944)

IT is hardly necessary to emphasize the importance of the study of sound in this day of recording phonographs, public address systems, and console radios. Acoustical principles play an important part in the design of our modern homes and the conveniences they contain. Furthermore, students are always interested in echoes and the resonant qualities of rooms. In spite of this obvious need and latent interest, the amount of time devoted to the study of sound in our general physics courses is often pitifully small. The Kundt's-tube experiment, the sonometer, and the resonance-tube experiment usually constitute the entire laboratory curriculum in sound. In the accelerated programs the first two of these are often omitted for the sake of time.

Acoustical or mechanical analogies are excellent student interest catching devices and serve an important function in teaching the principles of electric circuits. A few of the standard physics laboratory experiments in mechanics are adaptable to studies of resonance oscillations, but the acoustical analogies have been slighted. This is probably due to the difficulty of obtaining precise measurements. It is hoped that the present paper will increase the interest given to the study of sound in the laboratory. It will certainly increase the accuracy of the results in a resonance-tube experiment. Its application to the Helmholtz resonator, as here described, affords an additional laboratory experiment of considerable value.

CONSTRUCTION OF A RAYLEIGH DISK

The Rayleigh disk employed in this application consisted of a 2A microscope cover glass which is three quarters of an inch in diameter. It was painted white to make it more visible. Any flat circular disk would suffice so long as it were large enough. The turning moment on the disk varies with the third power of its radius.[1] The disk was attached to a suspension filament and hung from a torsion head. In this application a 0.002-cm gold suspension as used in D'Arsonval galvanometers was employed. The disk was attached to the suspension by laying it on a flat surface and drawing the suspension diametrically across it until about two centimeters extended on one side. Two small flakes or crumbs of sealing wax were then placed on either side of the disk and fused by bringing the heated end of a glass rod near to them. This cemented the suspension to the disk. The longer end of the suspension was then affixed to a torsion head and the shorter end was made to dip into a small cup of light oil which served to dampen oscillations resulting from air drafts. With this arrangement the disk may be used to indicate resonance in closed tubes and cavities since it will set itself diametrically across any constant or oscillatory, unidirectional stream of air. The sensitivity will of course depend upon the torsion constant of the suspension and upon the radius of the disk.[2]

APPLICATION TO A HELMHOLTZ RESONATOR

The principal application made by the authors was the experimental verification of the theoretical resonant frequencies of a Helmholtz resonator of variable dimensions. The complete apparatus is shown in Fig. 1. The resonator consisted of a large tin can, such as used for citrus fruit juices, having a volume of 1475 cubic centimeters. An orifice was made about a third of the way from the top which could be fitted with tubes of various lengths and diameters. A small funnel was soldered into the hole in the top of the can. This funnel, which was stopped with cotton when readings were taken, facilitated the reduction in volume of the can by pouring in measured amounts of water.

The resonator was placed so that the Rayleigh disk hung as close as possible to the end of the tube. The disk was adjusted so that its plane was

[1] W. Koenig, Ann. d. Physik **43**, 43 (1891).

[2] J. W. S. Rayleigh, Phil. Mag. **14**, 186 (1882).

at about forty-five degrees with the axis of the tube. A Hewlett Packard model 200C audio oscillator, driving a Hallicrafters permanent magnet speaker placed within a few feet of the resonator, provided a source of sound of variable frequency.

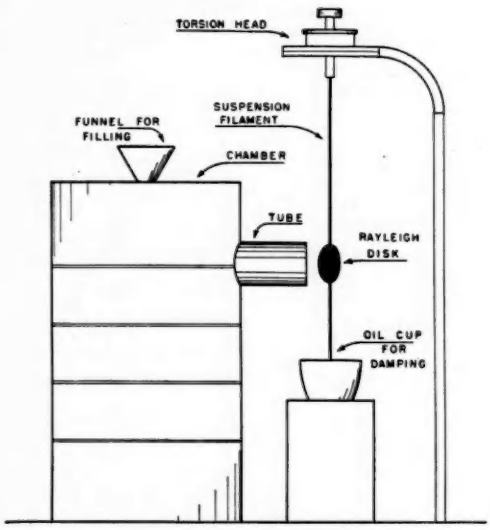

FIG. 1. Assembly of apparatus.

Provided that the length of the tube is small compared with the wave-length of the sound employed, the tube and chamber are analogous to a series electrical circuit of resistance, inductance, and capacitance. The resonant frequency is given by the well-known relation:

$$f_r = 1/2\pi(LC)^{\frac{1}{2}}. \tag{1}$$

The equivalent parameters for capacity and inductance are:[3]

$$C = V/\rho c^2. \tag{2}$$

$$L = \rho\frac{[l+(\pi/2R)]}{\pi R^2}, \tag{3}$$

where ρ is the density of air, c is the velocity of sound in air in cm sec.$^{-1}$, l is the length of the tube in cm, R is the radius of the tube in cm, and V is the volume of the chamber in ml. The factor $(\pi/2R)$ in Eq. (3) is the minimum value of the correction for the length of the tube.[4] Substituting the equivalent parameters of capacity and inductance into Eq. (1), we secure the expression for the resonant frequency of the tube and chamber:

$$f_r = \frac{c}{2\pi\left[\left(\frac{l}{\pi R^2}+\frac{1}{2R}\right)V\right]^{\frac{1}{2}}}. \tag{4}$$

Determinations of the resonant frequency of the tube and chamber were made using three different tubes and at various volumes obtained by pouring water into the chamber. The agreement of experimental and theoretical values was quite close as shown by the graphs of Fig. 2.

The experiment should be very satisfactory in a general physics laboratory because of the positive and critical response of the disk as an indicator and because of the relative simplicity of the experimental set-up. The audiofrequencies employed were low enough to permit the performance of the experiment in a laboratory where other people are working without the interference of discomfort which usually attends experiments with sound.

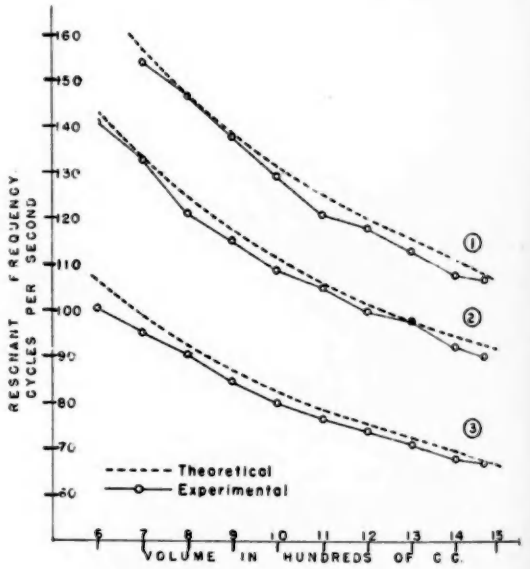

FIG. 2. Frequency response of a Helmholtz resonator. $f_r = \frac{c}{2\pi\left[V\left(\frac{L}{\pi R^2}+\frac{1}{2R}\right)\right]^{\frac{1}{2}}}$. (1) $L=5.0$ cm, $R=1.1$ cm. (2) $L=9.3$ cm, $R=1.2$ cm. (3) $L=18.5$ cm, $R=1.2$ cm.

In addition to the exercises outlined above, the

[3] G. W. Stewart, Phys. Rev. **20**, 528 (1922).
[4] J. W. S. Rayleigh, *Theory of Sound* (Macmillan, London, 1896), Vol. 2, p. 231.

fundamental frequency of a closed tube was very sharply detected. A number of additional applications are of course possible. For example, with suitable variations in the manner of support the Rayleigh disk might be used to advantage in the study of acoustical filters and horns. The principal use of the disk at the present time is the calibration of microphones and the standardization of sound sources.[5] These applications require laboratory facilities too elaborate for general scholastic use. This simple resonator experiment is particularly well adapted to the general physics laboratory curriculum as a combination study of resonance phenomenon and of the Rayleigh disk.

[5] H. F. Olson and F. Massa, *Applied Acoustics* (The Blakiston Company, Philadelphia), p. 231.

Erratum: Practical Hearing Aid Measurements

[J. Acous. Soc. Am. 16, 45 (1944)]

R. W. Carlisle and A. B. Mundel
Sonotone Corporation, Elmsford, New York

On page 47, in the third line from the end of the section on the "Artificial Voice," the term "pressure" should have been used rather than "intensity," which implies the square of pressure. The sentence should read:

"Inspection of these curves, one of which is taken at 1 foot and the other at 2 feet separation from the artificial voice, shows that, since the pressure is substantially 6 db less at 2 feet than it is at 1 foot, the pressure is reduced in proportion to the distance from the source."

Letter to the Editor

MAYER B. A. SCHIER
New York, New York
August 8, 1944

I WISH to include within *The Journal of The Acoustical Society of America*, as a matter of record, and in the interests of accuracy, some corrective comments which were rendered on the paper "Acoustic filtration and hearing aids" by Grossman and Molloy, at the May meeting in New York.[1]

This paper endeavors by laboratory demonstration to substantiate certain theories which Grossman offers as the basis for a supposedly new or novel type of individual earpiece for the conduction of the higher frequencies emitted from the receiver of a hearing aid into the deafened ear of nerve type cases. In practical form, he suggests an earpiece with a very short tip, a sound bore of extreme diameter, and interposed between earpiece and receiver a little gadget presumably to vary the air column. It is a matter of fact that the intent and practice are neither new nor novel.

It so happens that I have been quite involved in this problem for a good many years. I initiated the practice of having every air conduction instrument fitted with an individual earpiece—a procedure which is practically universal today, and a focal point of acoustic engineers, physicists, and governmental agencies.

In a prior article in an otological publication, Grossman endeavors to validate his efforts and includes a very inaccurate explanation of and reference to my advocacies.

If I can do nothing else within this brief opportunity, I wish to leave with you my personal concepts of a correct and simple understanding of conditions essential to the fitting of the deafened.

To simplify and standardize the problems in the fitting of ears by auditory prosthesis, for more than a decade and half I have advocated—and the overwhelming use of the sensitive or so-called high fidelity vacuum instrument has only served to strengthen that belief—that an impression of the ear should be as long as the patient can reasonably tolerate entry, or to include at least one-half inch of the actual auditory meatus.

For any consistency of approach, we should have a media that will permit a rational and consistent basis for evaluating sound conduction through the meatus without interference from the vagaries of meatal form. Hence, the longer tip. I have suggested in addition thereto that the earpiece be as passive an acoustic material as may possibly be obtained, and so developed and introduced the polymeric acrylic earpiece; and further, as large a channel or sound bore should be utilized as will permit a mean diameter for the greatest number of ears.

From here on, one can scientifically evaluate the effects of the conductive media on the frequency and other characteristics of an instrument. In this manner a rationale of approach can be established as a basis, and the earpiece varied or modified as may befit the needs of the individual ear.

Pertinent to this, let me close with a little experiment, substantiative of this projected approach and of demonstrative clinical value.

It has been advanced that the rehabilitative needs for reasonable intelligible intercourse ranges between the frequencies of 500 to 3000 cycles. An instrument was placed on an electric ear and its characteristics graphed. I made three little tube fittings in simulation of earpiece sound channels. With all conditions fixed, as in the graphing of the instrument alone, with the interposition of the first tube there was a reduction of the lows and the maintenance of the highs; with the second tube, there was obtained an appreciable rise in the lows to about 1000 cycles and a gradual descent and leveling of the rest to about 2500; with the third, there was an appreciable rise to about 800, a decline in the middle range, and then a very considerable rise in the range of 2000. This experimental demonstration of clinical experiences was performed for me by qualified acoustic engineers and a physicist in April of 1939 (see Fig. 1).

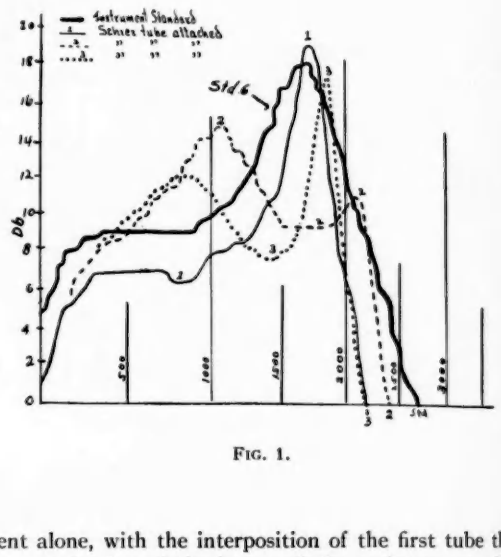

FIG. 1.

The tubes were all of the same diameter, excepting that filtration and diversion efforts were made to change the characteristics of sound during actual transmission as would occur in properly made, reasonably long-tip earpieces.

[1] F. M. Grossman and C. T. Malloy, J. Acous. Soc. Am. 16, 52 (1944).

Acoustical Society News

New Members

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Clarendon Hills, Illinois
Chief Engineer
4916 West Grand Avenue
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Paul A. Campbell, Lt. Col., MC
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Pawtucket, Rhode Island
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Fort Monmouth, New Jersey

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Permoflux Corporation
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Resigned: Ernest H. Peabody, member

Members	809
Fellows	179
Total Membership	988

Current Publications on Acoustics

F. A. FIRESTONE
3059 Randall Laboratory, University of Michigan, Ann Arbor, Michigan

Book Review

The Physics of Music. ALEXANDER WOOD, D.Sc. Pp. 255+xii, Figs. 91, Illustrations 109, 5¾″×8¾″. The Sherwood Press, Cleveland, 1944. Price $8.00. (Special introductory price $6.00, subject to cancellation without notice.)

The author offers both the musician and the physicist a very stimulating review of the literature dealing with the newer research in the physical bases of music. With the rich experience gained in writing a number of texts in this interesting borderline field, the author approaches the subject on quite an unsophisticated level in the present volume. This is, no doubt, done to avoid discouraging the musician. Yet the physicist can also profit by the great number of references to situations beyond the stage of first approximations of the classical literature. Probably the most startling innovation from the point of view of the physicist is the inclusion of a considerable treatment of the psychology of music.

The Journal of the Acoustical Society of America can be justly proud of the many references made to its contributors. The author skillfully interweaves the diverse bits of research accomplished during the past decade or more into a well-integrated and meaningful pattern, nicely augmenting the classic experiments of the pioneers in this borderline field.

Even the despised musicologist (for the term seems to cover a multitude of sins) comes in for a share of glory in the consideration of aesthetic values. To cap the climax, notions of musical expression and interpretation are even suggested in the chapters on voice and orchestral instruments. There are a few naive confusions of terminology in these chapters on musical instruments, which do not, however, detract materially from the good of the whole. The author's friends in the musical world will delight in pointing these errors out to him and future editions of the book can correct them. The hope of finding a few such mistakes should challenge the musician to read the text more carefully.

The acoustics of the auditorium is especially well treated. This particular chapter includes a wealth of illustrative material. In fact, the entire text is extraordinarily well supplied with diagrams and various types of illustration. It is for this reason, probably, that this volume is to cost as much as $8.00. This is really too much for a beginner's textbook, and it may unfortunately serve to limit the output to the chain of interested libraries.

ABE PEPINSKY
Haverford College

References to Contemporary Papers on Acoustics

MOST of the titles of papers appearing in other languages than English have been translated. Abstracts in English of many foreign papers have appeared or soon will appear in Science Abstracts, Section A. Where references are made to Science Abstracts, the reference is to the volume number and abstract number. The abbreviations of the names of journals are those used in Science Abstracts and can be found in any annual index to those abstracts.

The numbers appearing at the head of each entry are the numbers which identify the subject headings in the Cumulative Index of this Journal issued in November, 1939. The same Classification of Subjects can be found in the index to Volume 15.

Compiled with the generous assistance of Samuel Sass, Physics Librarian, University of Michigan.

2. ARCHITECTURAL ACOUSTICS

2.9 **Theory of Sound-Damming of a Thin Wall at Oblique Incidence.** L. CREMER. Akust. Z. **7**, 81–104 (1942); Abstract in Math. Reviews **5**, 194 (1944).

4. EAR AND HEARING

4.4 **A Correlation Between Vestibular Function and Hearing in the Profoundly Deaf Child.** M. F. VASTINE. Arch. Otolaryng., Chicago **39**, 164–171 (1944).

4.4 **A Family History of Deafness.** C. KABAT. J. Hered. **34**, 377–378 (1943).

4.4 **Hearing—a Postwar Problem.** J. C. HOWARD. Ann. Otol., etc., St. Louis, **52**, 843–849 (1943).

4.4 **A Selected Bibliography on Hearing and Deafness.** R. CARHART AND G. PETERSON. J. Speech Disorders **8**, 254–256 (1943).

4.4 For references on deafness see Volta Review.

4.5 **A Hearing Aid Clinic.** B. H. SENTURIA, S. R. SILVERMAN, AND C. E. HARRISON. J. Speech Disorders **8**, 215–226 (1943); see **17**, 3021.

4.5 **Clinical Audiometry.** C. C. BUNCH. (Mosby, St. Louis, 1943), pp. 186, $4.00.

4.5 **Hearing More for Less; Two Plastic Parts, Amplifier Unit and Earphone Tube.** Mod. Plastics **21**, 82–83 (April, 1944).

4.5 **A Comparative Analysis of the Results of Testing Individual Hearing-Aids in a School for the Deaf.** J. UTLEY AND M. GOEGEL, Speech Monogr. **10**, 40–49 (1943).

4.6 **The Reality of the Zero Reference Line for Pure Tone Testing.** H. WESTLAKE. J. Speech Disorders **8**, 285–288 (1943).

4.6 **Group Testing of Hearing.** R. WEST. J. Speech Disorders **8**, 279–283 (1943).

4.6 **Accuracy of Recognition of Subliminal Auditory Stimuli.** J. W. COYNE, H. E. KING, J. ZUBIN, AND C. LANDIS. J. Exp. Psychol. **33**, 508–513 (1943).

4.9 **Variations in Pitch.** L. A. JEFFRESS. Amer. J. Psychol. **57**, 63–76 (1944).

5. Applied Acoustics, Instruments and Apparatus

5.1 **Simple Sensitive Flames.** E. N. DA C. ANDRADE. Nature **153**, 498 (April 22, 1944).

5.1 **A Machine for Harmonic Synthesis.** A. SHILTON. Proc. Phys. Soc., Lond. **56**, 130–132 (March 1, 1944).

5.1 **A Sound-Operated Relay Control.** L. K. CONN. QST **28**, No. 8, **33**, 59 (August, 1944).

5.4 **Device for Automatic Recording of the Electroacoustical Characteristics of Emitting, Transmitting, or Receiving Systems.** P. CHAVASSE. Comptes rendus **216**, 722–723 (May, 1943).

5.4 **A Machine for Harmonic Synthesis.** A. SHILTON. Proc. Phys. Soc., Lond. **56**, 130–132 (March 1, 1944).

5.8 **"Salad Bowl" Horn, Designed for Speech Reproduction.** Electronics **17**, No. 6, 314 (June, 1944).

5.8 **Control Organ for Compressed-Air Loudspeaker,** (Patent) O. VIERLING. Hochfrequenztechn. u. Elektroakustik **62**, 96 (Sept. 1943); Wireless Engineer **21**, Abstract 1965 (1944).

5.8 **Dynamic Loudspeaker with Metallic Vibrating Element.** (Patent) S. SAWADE. Hochfrequenztechn. u. Elektroakustik **62**, 96 (Sept. 1943); Wireless Engineer **21**, Abstract 1964 (1944).

5.8 **The Mode of Action of the Rochelle-Salt Torsional Strip in the Direct and the Reciprocal Piezoelectric Effects.** H. KELLER. Hochfrequenztechn. u. Elektroakustik **62**, 66–73 (Sept. 1943); Wireless Engineer **21**, Abstract 1961 (1944).

5.9 **The Mode of Action of the Rochelle-Salt Torsional Strip in the Direct and the Reciprocal Piezoelectric Effects.** H. KELLER. Hochfrequenztechn. u. Elektroakustik **62**, 66–73 (Sept. 1943); Wireless Engineer **21**, Abstract 1961 (1944).

5.13 **Method of Reducing the Acoustic Feedback Between Microphone and Loudspeaker.** L. BIALK AND G. STEPHANUS. Hochfrequenztechn. u. Elektroakustik **62**, 94 (Sept. 1943); Wireless Engineer **21**, Abstract 1968 (1944).

5.15 **Device for Automatic Recording of the Electroacoustical Characteristics of Emitting, Transmitting, or Receiving Systems.** P. CHAVASSE. Comptes rendus **216**, 722–723 (May, 1943).

5.16 **A Simplified Variable-Density Sound Negative Developer.** P. ZEFF AND S. J. TWINING. Jour. Soc. Motion Pict. Eng. **42**, No. 5, 315–324 (May, 1944).

6. Musical Instruments and Music

6.1 **Contributions of Science to an Appreciation of Music.** A. PEPINSKY. Proc. Music Teach. Nat. Ass., pp. 94–112 (1943).

6.1 **An Unexplored Musical Source.** E. MURRAY AND H. L. EDSALL. J. Franklin Inst. **237**, 451–467 (June, 1944).

6.7 **Physical Aspects of Violin Tone.** J. D. MASTER. Music Educators J. **29**, No. 5, 22–23 (1943).

7. Noise

7.1 **Do We Love Noise?** A. R. WILLIAMS. Occup. Psychol., Lond. **18**, 35–40 (1944).

7.1 **What Constitutes Excessive Industrial Noise.** C. G. WYDER. Factory Management **102**, 141–143 (May, 1944).

7.1 **Strange Antics of Insect Musicians.** E. F. PHILLIPS. Sci. Digest **16**, 69–72 (Aug. 1944).

7.1 **Industrial Noise.** D. A. MCCOY. J. Ind. Hygiene **26**, 120–123 (April, 1944).

7.1 **Noise in Industry.** C. G. WYDER. Factory Management **102**, 137–156 (May, 1944).

7.1 **Some Facts on Industrial Noise.** Safety Eng. **86**, 67 (May, 1944).

7.7 **Park Avenue Noise Mystery; Effect of Fan Installation at Ruppert Power Plant.** A. W. KRAMER. Power Plant Eng. **48**, 92–95 (April, 1944).

9. Speech and Singing

9.6 **Speech-Training Machine.** Electronics **17**, No. 6, 105 (June, 1944).

10. Supersonics (Ultrasonics)

10.1 **Supersonics at Work.** K. HENNEY. Sci. American **171**, 10–12 (July, 1944).

10.3 **Flatness and Parallelism, in Quartz Plates.** G. M. THURSTON. Bell Lab. Records **22**, No. 10, 435–439 (June, 1944).

10.3 **The Mode of Action of the Rochelle-Salt Torsional Strip in the Direct and the Reciprocal Piezoelectric Effects.** H. KELLER. Hochfrequenztechn. u. Elektroakustik **62**, 66–73 (Sept. 1943); Wireless Engineer **21**, Abstract 1961 (1944).

10.3 **Principles of Mounting Quartz Plates.** R. A. SYKES. Bell Syst. Tech. J. **23**, 178–189 (April, 1944).

10.4 **The Problem of the Measurement of Absorption in the Supersonic Region.** H. BORN. Zeitschr. f. Physik **120**, 383 (1943).

11. Waves and Vibrations

11.1 **On Whistling Meteors.** S. R. KHASTGIR. Indian J. Phys. **17**, 239–245 (Oct. 1943).

11.3 **The Doppler Effect when Both Source and Observer Are in Motion.** G. F. H. HARKER. Amer. J. Phys. **12**, 175–177 (June, 1944).

11.4 **The Sound Field of a Radiator in a Layer of Medium with Acoustically "Soft" and Acoustically "Hard" Boundaries.** H. STENZEL. Ann. der Physik **43**, 1–31 (June 26, 1943); Wireless Engineer **21**, Abstract 1984 (1944).

11.4 **The Calculation of the Sound Field of a Circular Piston Diaphragm.** H. BACKHAUS. Z. Techn. Phys. **24**, 75–78 (1943); Abstract in Math. Reviews **5**, 195 (1944).

11.7 **The Doppler Effect when Both Source and Observer Are in Motion.** G. F. H. HARKER. Amer. J. Phys. **12**, 175–177 (June, 1944).

11.7 **Theory of the Spherical Wave Excited at a Finite Distance from the Surface of Demarcation of Two Media, for Finite Refractive Indices.** M. KRÜGER. Zeitschr. f. Physik **121**, 377–437 (Aug. 10, 1943).

11.7 **General Vibration of a Hinged Beam.** H. K. BROWN. J. Appl. Physics **15**, 410–413 (May, 1944).

11.7 **Theoretical Analysis of Modes of Vibration for Isotropic Rectangular Plates Having All Surfaces Free.** H. J. MCSKIMIN. Bell Syst. Techn. J. **23**, 151–177 (April, 1944).

11.7 **The Reflection and Refraction of Acoustic Waves at the Surface of Separation of Two Fluids at Rest and in Motion of Translation.** E. ESCLANGON. Comptes rendus, Paris, **215**, 45–48 (1942); Abstract in Math. Reviews **5**, 194 (1944).

11.7 **An Oscillation Phenomenon in Fluids with a Stable Density Stratification.** H. GÖRTLER. Z. angew. Math. Mech. **23**, 65–71 (1943); Abstract in Math. Reviews **5**, 193 (1944).

11.7 **The Propagation of Shock Waves in a Canal.** M. S. MARANZ. Applied Mathematics and Mechanics (Prikladnaia Matematika i Mekhanika), Leningrad **7**, 179–192 (1943); Abstract (in French) in Math. Reviews **5**, 193 (1944).

THE JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA VOLUME 16, NUMBER 2 OCTOBER, 1944

Review of Acoustical Patents

ROBERT W. YOUNG
C. G. Conn, Ltd., Elkhart, Indiana

Printed copies of patents are furnished by the Patent Office at a cost of 10¢ each. Address all communications to: The Commissioner of Patents, Washington, D. C. Remittance may be made by money order, certified check, cash, or special coupons which are sold in blocks of twenty or books of one hundred.

The decimal numbers appearing before titles are those which identify the headings being used in the analytic subject index of this journal. The Patent Office classification given in parentheses with each patent entry is outlined in the "Manual of Classification of Patents" which is obtainable from the Superintendent of Documents for $1.50.

Unless otherwise indicated, patents listed have been issued on the date shown by the United States Patent Office.

Reviewers

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FRANK H. SLAYMAKER, *Stromberg-Carlson Company, Rochester, New York*

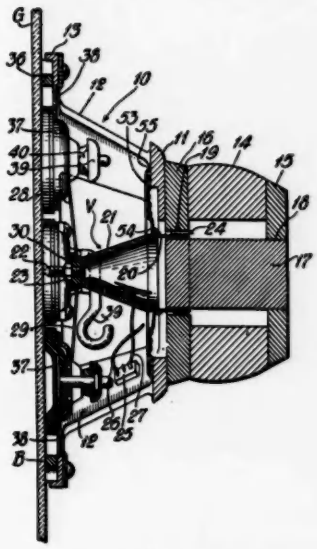
R. W. YOUNG, *C. G. Conn, Ltd., Elkhart, Indiana*

2,341,275

5.8 SOUND REPRODUCING INSTRUMENT

Glen Holland.
February 8, 1944, 12 claims (Cl. 179–115.5).

Here is the familiar moving coil loudspeaker adapted to drive a solid medium such as a plate glass window. The motion of the voice coil is transmitted to the medium



through a conical structure **21**, and a stylus **22**. Vacuum cups **37** serve to fasten the device to the window glass.

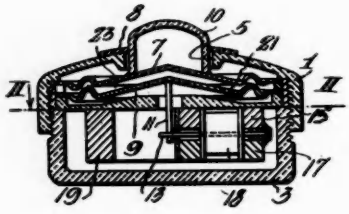
The stiffness which is necessary to hold the stylus against the glass may be provided either by a "rubber bearing" between the voice coil and the central pole piece or by stretched wires **28** and **29**.—FHS

2,345,996

5.9 SIGNAL TRANSLATING APPARATUS

Leslie J. Anderson and Alfred H. Kettler, assignors to Radio Corporation of America.
April 4, 1944, 5 Claims (Cl. 179–116).

The "signal translating apparatus" described in this patent is an electromagnetic balanced-armature type throat microphone. The constant pressure against the throat



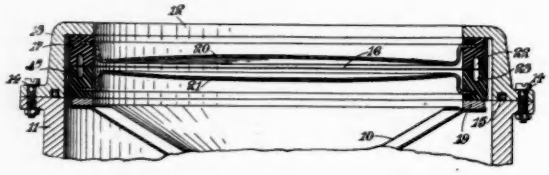
which might force the armature against the pole pieces is removed from the armature by the use of two diaphragms **7** and **9** coupled by the air between them. In one of these diaphragms is a small hole **21** which provides an air leak to the atmosphere.—FHS

2,346,226

5.9 PROTECTIVE COVER FOR APERTURES FOR LOUDSPEAKING INSTRUMENTS, MICROPHONES, AND OTHER ARTICLES

Dennis Herbert Marlow, assignor to British Rola Limited.
April 11, 1944, 7 Claims (Cl. 160–380).

The protective cover includes an oil-silk membrane **16** intended to prevent the entry of water to the loudspeaker.



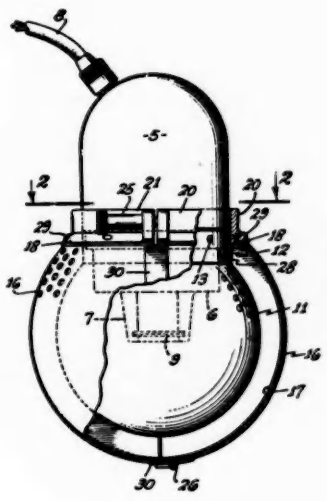
To prevent rupture of the membrane by a high intensity shock wave, the motion of the membrane is restricted by protective grids **20** and **21**.—FHS

2,346,394

5.9 SOUND PICK-UP APPARATUS

Michael Rettinger, assignor to Radio Corporation of America.
April 11, 1944, 9 Claims (Cl. 179–188).

The emphasis, in this patent, is primarily on the con-



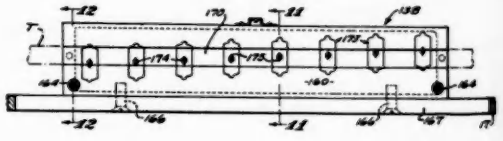
struction of wind screens for broadcast type microphones. —FHS

2,335,277

5.16 MAGNETIC RECORDING MACHINE

Herman S. Heller.
November 30, 1943, 11 Claims (Cl. 179–100.2).

This magnetic recording machine has a plurality of recording, reproducing, and erasing devises which produce separate parallel records on a flat magnetic tape. The



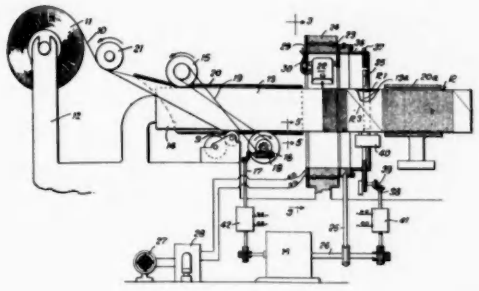
channels may be used either simultaneously or consecutively. For cases where more channels are required than may be put on one tape, the machine is arranged so that several tapes may be driven from the same driving means. A particular application disclosed is for use in the flight testing of aircraft.—LWS

2,343,114

5.16 RECORDING AND REPRODUCING SOUND

Leopold Neumann, assignor to Multiprises, Incorporated.
February 29, 1944, 9 Claims (Cl. 274–17).

This recording machine, intended primarily for dictation purposes, departs from convention. Continuous recordings are made on a cylindrical base which is formed from flat ribbon stock **11** around mandrel **14** by the aid of surrounding tube **20**. If it is desired to form the material perma-



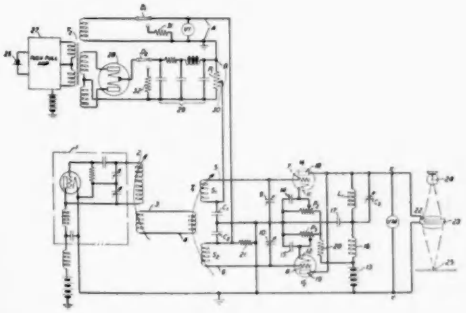
nently into a cylinder, adhesive may be applied by roller **9**. The resulting tube is advanced by rollers **15** and **16**. The helical sound track is produced by cutter **22** which is rotated around the mandrel by means of the annular carriage **23**. For storage the tube may be pressed flat.—LWS

2,343,182

5.16 SOUND RECORDING WITH SUPERSONIC MODULATOR

Frank P. Herrnfeld, assignor to Western Electric Company, Incorporated.
February 29, 1944, 6 Claims (Cl. 179–100.3).

This patent describes a means of applying noise reduction to a supersonic light modulator such as described by G. W. Willard in U. S. Pat. 2,287,587. (This is an applica-



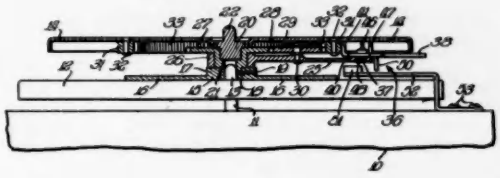
tion of the Debye-Sears supersonic grating.) In the push-pull modulator circuit shown in the figure, tube **V2** is biased as a class B amplifier and tube **V1** is normally biased slightly greater, resulting in a net carrier output across **XY**. Circuit **A** provides speech frequency modulation of the push-pull modulator grids while circuit **B** provides a varying bias on tube **V1** in accordance with the envelope of the speech waves. This results in a carrier output at **XY** which is always 100 percent modulated.—LWS

2,343,370

5.16 MULTIPLE-SPEED PHONOGRAPH TURNTABLE

Richard W. Sears, II.
July 11, 1944, 9 Claims (Cl. 274–9).

This patent describes a planetary gear arrangement by which an ordinary 78-r.p.m. turntable may be converted



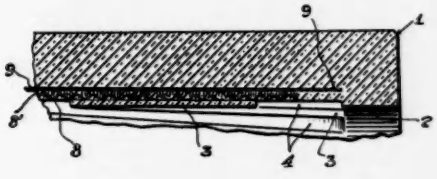
to a two-speed table so that slower speed "transcriptions" may also be played thereon.—LWS

2,346,597

5.16 PHONOGRAPH RECORD AND METHOD OF MAKING

Walter H. Miller, assignor to Thomas A. Edison, Incorporated.
April 11, 1944, 9 Claims (Cl. 18–48.3).

This patent relates to an improved method of making a waxlike phonograph record where a napped material such



as flannel **8** is placed on the bottom or inside of the mold. The many fibers of the nap make a strong bond to the wax, thus causing the record to be less subject to breakage in handling. The fuzz from the nap, however, may permeate the entire record resulting in high noise level. This is prevented by surrounding the flannel by a layer of filter paper **9** which is impervious to the lint. The filter paper also serves to strengthen the record.—LWS

2,349,886

5.16 PHASE MODULATION RECORDING AND REPRODUCING SYSTEM

Walter van B. Roberts, assignor to Radio Corporation of America.
May 30, 1944, 15 Claims (Cl. 179–100.4).

Phonograph recordings may be made by phase modulating a superaudible carrier according to the teachings of this patent. The detection of phase modulated waves

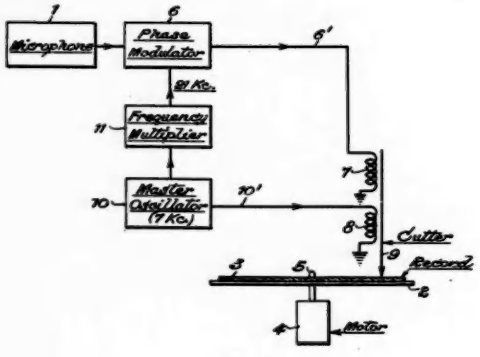


FIG. 1.

involves some difficulty in that an unmodulated carrier wave is required at the detector. This difficulty is easily surmounted by simultaneously recording a submultiple of

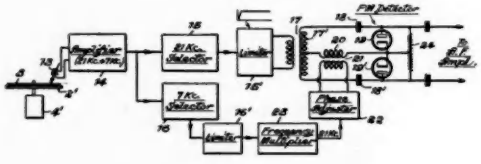


FIG. 2.

the carrier. In accordance with previously issued patent 2,334,510* this unmodulated wave may also be used for controlling the speed of the reproducer. Figure 1 shows a block diagram of the elements of the recording system while Fig. 2 shows those of the reproducing system.—LWS

* See J. Acous. Soc. Am. **15**, 240 (1944).

2,349,888

5.16 SOUND RECORDING SYSTEM

Chester M. Sinnett, assignor to Radio Corporation of America.
May 30, 1944, 2 Claims (Cl. 179–100.4).

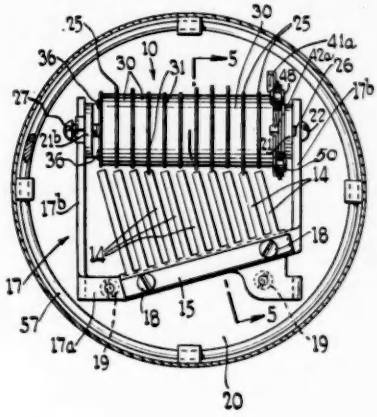
This patent covers a method of carrying volume control information on a recording by controlling the frequency of a superaudible oscillator and recording its output along with the program material. In reproduction the superaudible signal is filtered off and put through a frequency discriminator in such a manner as to restore the original signal. By making the frequency control during recording automatic, such as by using a reactance tube control, an automatic compression-expansion system results.—LWS

2,346,444

6.1 MUSICAL DEVICE

Leon G. Machlin and Elias B. Kriegsfeld, assignors to Metal Tone Corporation.
April 11, 1944, 8 Claims (Cl. 84–95).

This music box is designed especially to be inserted in a doll, the whole unit to be enclosed in a bellows. A set of pawls is carried on a lazy tongs movement so arranged that



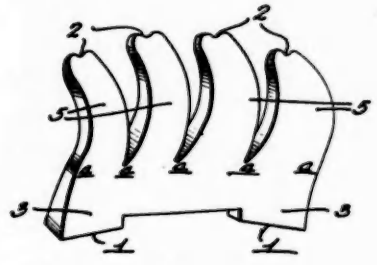
compression and release of the bellows causes drum **10** to rotate continuously in one direction. The projections **31** thus always lift the reeds **14** in the proper order to produce the melody.—RWY

2,343,384

6.7 MULTISTRINGED MUSICAL INSTRUMENT

John Isaac McDonald.
March 7, 1944, 1 Claim (Cl. 84–309).

In this bridge for an instrument such as a violin each string is supported by a column **5** which tapers both in



width and thickness and is curved as indicated in the figure.—RWY

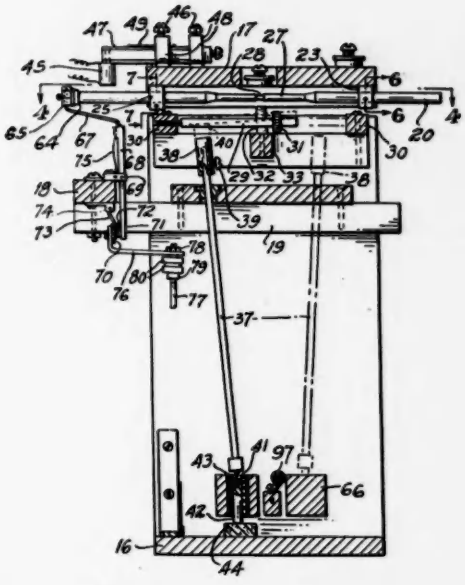
2,352,438

6.9 MUSICAL INSTRUMENT

John O. Hruby, Jr., assignor to Louis A. Maas.

June 27, 1944, 7 Claims (Cl. 84–1.04).

The rods **20** which serve as the vibrators in this electrically amplified musical instrument are of unique shape so as to afford two modes of vibration, the higher of which is two octaves above the frequency of the lower. The central third **27** of the rod is turned down until the approximate frequency relation is obtained and then the fine tuning is accomplished by cutting the groove **28**. This affects primarily the fundamental frequency; if it is carried too deep, other grooves may be turned at the ends of the small diameter section to lower the frequency of the higher mode to establish the double-octave interval. Then the frequency of both may be returned to the proper value by grinding the ends of the rod. Hammers **29** and dampers **64**



may be controlled by solenoids. The pick-ups **45** are connected to a suitable amplifying system.—RWY